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The new dynamometer wagon for horse studies ...

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THE NEW DYNAMOMETER WAGON FOR HORSE STUDIES

by

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BIBLIOGRAPHY

American Society of Agricultural Engineers Yearbook-1915

American Society of Agricultural Engineers Yearbook-1919

Principles of Industrial Organization -Kimball

Missouri Experiment Station Yearbook - 1910

Breeders Gazette-June 1921

Farm Motors- Potter

Marks Handbook

THE NEW DYNAMOMETER WAGON FOR HORSE STUDIES

Introduction:

The horse is used to generate power for such a large percentage of farm work that a careful study of his performance and general adaptability is necessary if we are to appreciate his strong points and overcome his weaknesses. The horse with the help of the mule has been the chief power generator for machinery which has enabled American farmers to product large crops with relatively little man labor. As is the case with any other motor, the horse should be studied from the view points of his over-all efficiency, cost of operation, and general adaptability, to the work which is to be done. Unfortunately, few reliable investigations have been conducted for the purposes of securing authentic information on the most important points. There is some work available regarding the cost of keeping farm horses, and the general facts regarding the adaptability of the horse can be taken from universal experience, but when it comes to over-all efficiency, the case is different. By over-all efficiency of a horse as a motor is meant the total useful work done divided by the total input of energy. This over-all efficiency may be determined more accurately by studying the main issues of the problem which are:

(a) Determining the capacity of horses and mules to do work.

(b) Finding the relation between work done and feed required.

(c) Determining the effect of varying the relation between periods of work and rest.

Many books and articles have been written regarding the origin of horses and breeds and types of horses, but all these works valuable as they are, fail to get down to the real heart of the question, "What is the horse capable of doing when used as a motor?"

Discussion:

A careful survey of the literature, American and Foreign, furnishes a slight amount of information regarding overall efficiency, enough so that by making reasonable assumptions a few general ideas may be obtained and used in the present horse test.

A foreign investigator named Luntz, after carrying on an elaborate series of experiments, reports that the horse can vitalize approximately 33% of the net energy available in the feed. His figures will agree with those of Hirn and would appear to be flattering the animal motor, if it were not for the fact that they were computed on the basis of net digestible nutrients in the feed after reductions had been made for the work of digestion, assimilation, and maintenance. It is really the percentage of available energy which the muscles of the body are able to transform into useful work. It corresponds to the efficiency of an internal combustion engine working under ideal conditions, which is between 35 to 40 percent provided allowances are made for internal friction, losses, and unburned fuel.

The heat energy in feeds is computed on the basis of therms in digestible nutrients, (one therm equals 1000 calories which is equivalent to 3,087,100 foot pounds). As a rule, not more than 75% of the total energy in the feed can be digested by the horse. On the average, hay yields 1.7 therms of gross energy per pound and grains 1.85 therms per pound. From our standpoint we are, however, interested in the over-all efficiency of the horse as used on the farm, in which case the total energy in the feed consumed must be compared with the total useful work done in a given period of time, say one day or one year. It is generally assumed that at hard work a horse will exert a pull equal to 1/10 of his weight at the rate of two miles per hour for a period of ten hours per day. Under these conditions a 1600 pound horse will do 16,896,000 foot pounds of useful work in ten hours. While at this work the horse will require approximately 1.3 pounds of grain and one pound of hay per 100 pounds of live weight per day. The gross energy in this feed is 65.7 therms, which is equivalent to 202,822,470 foot pounds. This would give an over-all efficiency of 8.3 % (being 16,896,000 divided by 202,822,470). If the rate of travel or the pounds pull can be increased on the same feed, the efficiency will be higher.

Our farm horses, however, do not work every day, but they must eat just the same. In order to determine the real over-all efficiency of a farm horse we should know the total feed consumed and the total work done in the course of a year.

Thomas A. Edison is reported to have said that the average farm horse has an over-all efficiency of two percent.

Experiments were performed at the Missouri Agricultural Experiment Station in which the yearly over-all efficiency of horses and mules on the farm was computed. These experiments were carried on in the year from 1909 to 1910, with four mules. Two of the mules were fed corn and hay and the other two were fed oats and hay. The mules fed corn and hay consumed 4,142,75 pounds of grain and 5,360,51 pounds of hay each and did 433.12 hours of heavy work, 197.5 hours of medium work and 1002.12 hours of light work. The oat fed mules consumed 4,288.5 pounds of grain and 5,424.87 pounds of hay each and did 374.75 hours of heavy work, 188.75 hours of medium work and 955.75 hours of light work. Assuming that the hay contained 1.7 therms of gross energy per pound, and the grain 1.85 therms of gross energy per pound, and that at hard work the mules exerted a pull of one-eighth of their weight at two miles per hour; at medium work one-twelfth of their weight at 2.5 miles per hour; and at light work one-sixteenth of their weight at 2.5 miles per hour. The corn fed mules had an over-all efficiency of 3.54% and the oat fed mules an over-all efficiency of 3.4%.

The mules worked between 1500 and 1600 hours per year. Considering that the average horse on the farm works but 800 to 1000 hours per year, it would appear that their yearly overall efficiency would be between two and three percent.

The above experiment was given here because it is the only one of which we have any record in which the horse was studied as a motor. It is something on the order of the test we are about to make so that a study of its facts will give us valuable points to work on and also ~~have~~ give us ideas of what to expect in some of our tests. This experiment touches upon the first two of our main issues lightly, but nothing has been done about the third, namely: The effect of varying the periods of work and rest. To our knowledge nothing on this order has ever been conducted before so that valuable data may be uncovered in the results of these tests. It is universally known that the horse is especially well adapted to variable loads, having a 300 to 400 percent overload capacity for short periods of time, but this is all taken for granted for there never have been any tests and data to prove many of the assertions made.

This test is therefore conducted for the purpose of learning more facts about the horse, when used as a motor.

<u>Objects to be Determined:</u>

The main issues to be determined are:

(a) The capacity of horses and mules to do work.

(b) The relation between work done and feed required.

(c) The effect of varying the relation between the periods of work and rest.

Plan of Procedure or Methods to be used in Testing.

With the above issues in view, certain closely related facts and objects were laid down on which to design the testing apparatus to be used.

(1) Build a dynamometer wagon to give a constant resistance to each of two horses. The resistance is to be adjustable independently for each horse. The wagon is to be equipped with a speedometer so as to enable the driver to maintain constant speed and an odometer to record the total miles traveled.

(2) A course of travel to be selected.

(3) A team for use in the test to be selected.

(4) The wagon is to be pulled over the chosen course every day except Sunday, for ten hours at 2.5 miles per hour. Starting with a pull of one-fifteenth of the horses weight and increasing the pull each day until the horse is losing in weight. The load will then be adjusted daily to determine the load which will allow the horses to maintain constant weight. A weight of 1/100 pounds is suggested as a suitable increase to be added daily until the horse is losing weight.

(5) Make similar tests as follows:

(a) Eight hours working time with intermittent periods of rest.

(b) Eight hours working time without rest.

(c) Five hours of working time with intermittent periods of rest.

(d) Five hours of working time without rest.

(e) Ten hours working time at two miles per hour.

(f) Ten hours working time at three miles per hour.

Data to be Secured.

(1) A complete description of the horses used.

(2) The amount and kinds of feed used and the time of feeding.

(3) The weight of each horse to be taken at the same time each day.

(4) The temperature of the air to be taken each hour on the wagon, and a general description of the weather conditions.

(5) The angle of the traces.

(6) The amount of resistance applied to each horse each day.

(7) The total distance traveled each day, by odometer reading.

(8) The condition of the course traveled, daily.

(9) Humidity and barometric pressures daily.

Design and Description of the Apparatus with Changes for Each Trial Test Until Wagon is up to Successful Working Form.

To meet the requirements laid down by the horse testing plan, a wagon was designed, taking the International Harvester Auto Wagon (old model) as a nucleus for the plan design, because it was easily available. The entire auto wagon was dismantled and all parts were taken off until the framework of the chasis alone remained. The chain drives from the sprockets on the rear wheels to the jack shaft were allowed to remain intact as was the chain drive from the jack shaft sprocket to the point where the engine was formerly attached. The two brakes, the one acting on the inside of the rear wheel drums and the other on the jack shaft drum were allowed to remain undisturbed.

A large underslung platform was then built and attached to the wagon by means of eight ½"x9" carriage bolts which fastened into the step on each side of the wagon. This permitted the platform to hang twelve inches below the frame, thus allowing the pump to be set in. The platform was constructed of 1"x4" pine flooring which was fastened to two 1-5/16"x8" planks. A bar of iron designed to fit on the bottom of the flooring and take the carriage bolts, strengthened the floor and kept it from spreading and splitting.

The platform was 5½ft. wide and three feet long. The flooring was further strengthened by two 2"x4" wooden braces nailed across the bottom,

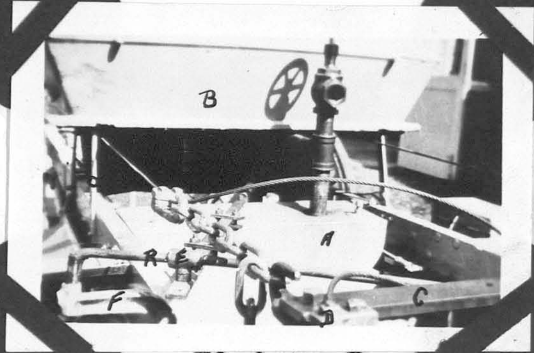
A rotary gear force pump was next placed on the platform in such a manner that the gear wheel on the pump shaft would be in line with the jack shaft sprocket ~~gear~~, and capable of being run from the former. The base of the pump was then fastened to the platform floor by means of three machine bolts, care being taken to have a clearance of the pump base from the floor of about three-eights inch. This was accomplished by inserting washers under the pump base and then fastening with the bolts. This arrangement gave the pump a three point suspension which had the advantages of allowing the pump to run free at all times even though ~~with~~ the wagon platform was shifting and bending. The force pump was a rotary gear force pump capable of delivering a force and pressure of 100 pounds at capacity. The pump was to be run at a speed of 250 R.P.M. and in order to accomplish this the gear ratios on the drum to the jack shaft and on the jack shaft drive to the pump had to be calculated. These sprockets were taken as they were, but their ratios were calculated to make sure they would give suitable a speed to the pump of from 200 to 300 R.P.M. The rear wheel sprockets had 87 teeth and the sprocket on the jack shaft run from this sprocket had 14 teeth which made a gear ratio of 6-3/14 to 1.

The jack shaft sprocket had 22 teeth and the pump shaft sprocket in order to drive the pump at 250 R.P.M. with the wagon traveling 2.5 miles per hour had to have 15 teeth.

The pump was connected to a ten gallon tank by means of a two inch pipe which led from the bottom of the tank to the inlet of the pump. Tank can be seen at (A) in picture 9 or (B) in 8 . At the top of the pump is fastened a balance control valve which is supposed to regulate the flow of water thru the pump and into the tank. The outlet is attached to this control valve and leads the water from the pump back thru a two inch pipe into the top of the tank. The opening and closing of this valve relieves and holds pressure in the pump thus requiring different amounts of power to operate it at different openings.

In order to install the working machinery properly a framework was needed which would stand up under severe strains. The base of the frame was made of $\frac{1}{2}$"x2" iron stock so as to be durable. Two pieces were cut to dimensions $\frac{1}{2}$"x2"x30" and fastened to the front end of the wagon frame in such a manner that the ends of the iron protruded over the front ends of the frame six inches and were attached by six cap screws, three on a side (A picture 3). Another bar was cut to dimensions $\frac{1}{2}$"x2"x47" and bent up at right angles six inches from each end. This was the top bar. (B in picture 3) (B in picture5) A bottom bar was cut to dimensions $\frac{1}{2}$"x2"x35" and placed as shown in picture (C in 3) or ~~C~~C in 5).

Three spindles were placed in a lathe and turned down to a one inch diameter and a three-fourths inch diameter at the ends. These ends were later threaded so that the



Picture 9

A-Tank

B-Seat

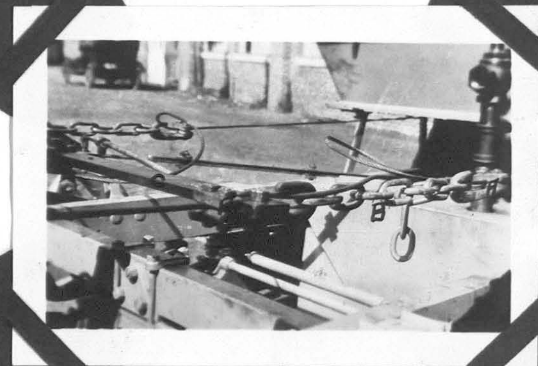
C-Cable-bar

D-Cable-clamp hook

E-Adjust socket

F-Eyesocket

R-Cable-bar rod

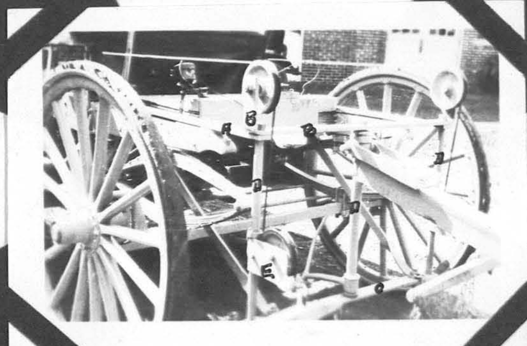


Picture 8

A-Cable-clamp hooks

B-Cable adjusting chain.

C-Cable-bar



Picture 3

A-Bar on frame

B-Top-bar holding sheaves

C-Bottom-bar of frame

D- Spindles

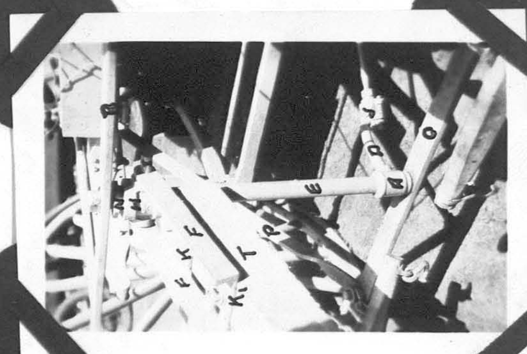
E-Adjustable sheave cases

T-Wagon tongue

K and K_1 - Brace pieces in steering apparatus

N-Pipe bushing

P-Frame brace



Picture 5

A-Pipe tee

B-Top-bar holding sheaves

C-Bottom-bar of frame

D-Steering lever-arm

E-Center spindle

F-Side pieces of adjustable steering apparatus

H-Pipe-cross at top of spindle

I-Iron rods in pipe-cross

J- Steering-rod joint

dimensions between the threaded portions was $22\frac{1}{2}$". (D in 3). These spindles were fitted to the top and bottom bars in the front of the framework and placed at equidistant points, one at each end and one in the center. (D in 3).

The six inch sheaves which carried the steel cable were fastened to the top bar with specially designed spindles. The spindle was turned down in a lathe to the form shown in the blue print on the last page. The spindle had a small head on the one end about one inch in diameter which fastened to a portion five-eights inch in diameter and about one and one-fourth inches long. The diameter of the sheave containing the thread was three-fourths inches.

In fastening the sheave to the bar the method used was as follows: The spindle was thrust thru the hole in the sheave up to the head. A small collar, made out of a pipe, was fitted on and the spindle then thrust thru the hole in the bar. The nut on the other side fastened it securely in position yet due to the shape of the spindle and collar, the sheave was able to move freely without undue side motion. In position in (A picture 6).

Two more sheaves were placed in the front of the frame but these were encased in special sheathes and fastened to the end spindles as shown in (E picture 3) and (E picture 6).

The sheaves are held in place by special wrought iron collars which are clamped to the spindles by means of set screws, and the sheathes held in place on these collars by sliding hooks which permitted the side motion necessary but still kept the sheaves firm. Collar and hook shown as (B and C in picture 6) By adjusting the height of these collars on the spindle the height of hitch, which is directly controlled by them, is also controlled. This arrangement allows also for the setting of the angle of the traces.

The steering apparatus was the next fixture that had to be changed. As the Auto wagon was designed to be controlled by a wheel in the driver's hands, when used with horses this method of control would naturally have to be changed. The rod on the steering column where it fastened on to the steering rod was cut off about four inches above the steering knuckle. A piece of iron pipe about one inch in diameter was cut and fit over the center spindle in the wagon front. To the bottom end of this pipe was attached a pipe tee and below that a bushing and both welded to the pipe by use of the oxy-acetylene torch. A pipe cross was welded to the top of the one inch pipe and two ½"x3" rods placed in the end openings and welded to the cross. A bushing placed at the top of this pipe cross completed the top of the pipe.

Bars of iron were cut to the dimensions given - two were 3/8"x1"x6" and three were 3/8"x1"x3". The two large pieces were used as the side pieces on the special tongue holding and adjusting arrangement and were drilled at the ends so as to fit over the one-half inch iron bars extending from the side openings to the pipe cross. The three small pieces were welded to these side pieces to form the bottom of the device. The blue print on the last page shows the construction of this part. Picture five also shows the whole steering apparatus assembled and specifies the parts by letters and explains beneath the picture.

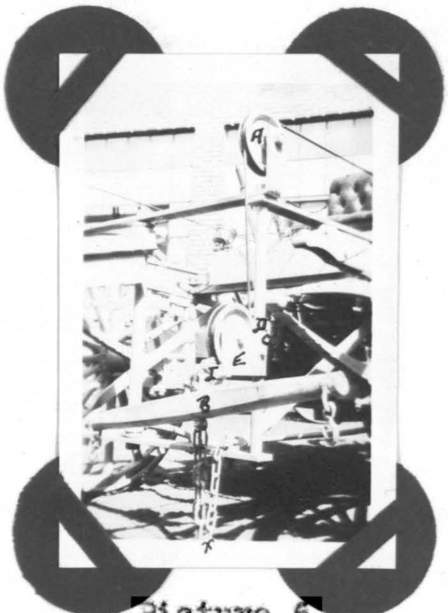
The part at K was slotted, which permitted the tongue to be arranged in such a manner so as to give various amounts of side draft of the wagon on the horses collars.

To keep the frame more steady and firm, two iron braces (D in 5) were attached to the ends of the bottom bar (C in 5) and the other ends attached to the main frame of the wagon.

On the rear end of the wagon a framework was built up somewhat similar to the one in the front of the wagon. A bar of iron similar to the top bar in the front was made to dimensions $\frac{1}{2}$"x2"x47 and the ends bent up in the same manner as the front bar as shown in (A picture 7). The bar was fastened on the end of the framework by means of three 3/8"x8" cap screws. The six inch sheaves were fastened with the specially designed spindles similar to those on the front top bar.

Running across the front and rear sheaves in line were two three-eights inch woven steel cables (A picture 15) Fastened to the rear ends of these cables were two fifty pound weights secured to the cable by screw eyes. On the front end the cables ran down from the top sheaves and around the encased sheaves on the spindles (A and E of picture 6) and then the end was attached to the eye of a single tree (B in 6). The cable was fastened with clamp (I of picture 6) which also acted as stop clamp and kept the weights from pulling the cable eyes thru the sheaves. A chain (X in picture 6), one end fastened to the eye bolt of the single tree and the other to the bolt of the brace bar, permitted the single tree to be drawn out eighteen inches from the encased sheaves and then halted the action. This acted as a guard to keep the horses from pulling the weights on the other end over the sheaves on the rear.

A bar 1/8"x1"x33" was made and fastened onto two loose fitting end joints having cable clamps attached. These clamps were fastened to the cables across the rear end of the wagon thus holding the bar in position. (A picture 10) The joints on the end of the bar would permit the one cable to travel forward eighteen inches before the cable rod would bind on the other joint and in this way perfect freedom in the draft of horses was obtained. Fastened to the center of this cable rod was a small eye socket fastened in such a manner so as to permit side motion. A rod of iron was fitted to a socket on



Picture 6

A-Sheaves

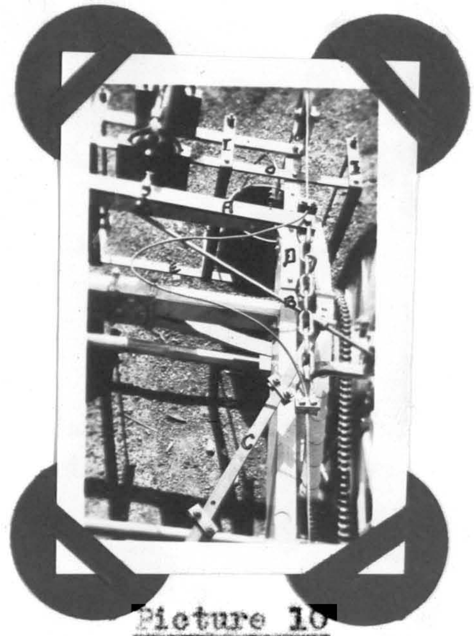
B-Single-tree

D-Adjustable sheave cases

E-Adjustable sheave cases

I-Cable-stop clamps

X-Single-tree stop-chain



Picture 10

A-Cable-bar

B-Cable-bar rod

C-Adjustable pump control bar

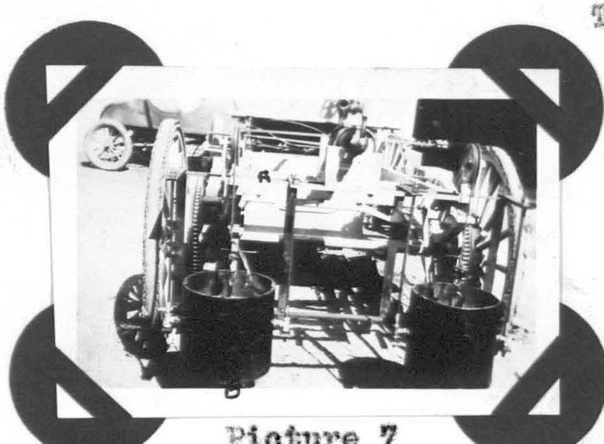
D-Angle bars holding frame-
work

E-Rear frame bottom-bar

I- E-shaped bucket rod holders

O- E-shaped bucket rod holder-
brace

Top view of control mechanism



Picture 7

A- E-shaped bucket-rod
holder brace

B-Bucket

Picture 15

Side view of wagon

A-Cable

the side of the wagon and when correctly bent the one end was placed thru the eye socket on the cable rod. Fastened on to this rod was a bar which was attached to the pump valve bar at the other end. This allowed for the reducing action necessary to act on the control valve. The action was as follows, if the clamp on the bar was placed closer to the eye socket on the side of the wagon, then the arc-shaped path swept over by this rod in motion would be smaller in size than that at the eye of the cable rod socket. This apparatus was the automatic control of the dynamometer wagon. Blue print on last page shows the design on the action. Picture ten also explains the parts making up the apparatus.

The seat was placed near the front end of the wagon and designed so that it could be easily taken off and replaced whenever necessary. Side irons were fastened to the wagon and the seat fitted to them and held in place by means of sliding bars which slid under the iron and held the seat securely. By unlatching these sliding bars, the seat was easily and quickly removed. (B and C in picture 9) The wagon was now complete and ready for the first trial. Two coats of Agricultural Engineering gray paint were then placed on the wagon before taking it out.

Before the action of the wagon during the first trial is explained, the desired action of the wagon will be stated and discussed.

Desired Action of the Dynamometer Wagon

The desired action of the dynamometer is in the first place, to move along smoothly at working speed for horses.

By means of the buckets or weights on the cable, any desired load may be placed on the horse which will remain constant thruout that trial.

Two horses are to be hitched to the dynamometer wagon, each being free to move forward and not being held back by a doubletree evener. When the horses move forward the single trees are drawn forwards thus drawing the cable forward over the sheaves. This in turn raises the weights in the rear and in drawing them upward the wagon moves forward. When the cables move forward, the cable rod (A in 10) is drawn along with the cables and in turn acts on the end of the rod (B in 10) which sweeps over a definite path and moves the rod (C in 10) fastened to it over a lesser degree. This rod (C in 10) then acts upon control valve rod and regulates the pressure on the pump. When the cable bar is moved forward the control valve is gradually opened thus causing less power to be required from the wheels to operate the pump. This causes the weights to drop again, drawing the cables back, which thus acts to close the control valve of pump again. Then the operation is repeated. The desired action of the valve is to keep the pressure at such a point that the power required to raise the weights is even and the weights will hang midway between the top and bottom positions of their limits of motion. This would automatically require the same amount of power to operate it during all the time of its motion and would control for the same amount of draft down-hill as uphill.

First Trial and Redesign to Remedy the Defects.

Two large percheon horses were selected to draw the wagon in the first trial and the course was the rough grass plot opposite the Agricultural Engineering building.

When the horses moved forward the wagon was noticed to take on a very unsteady motion much on the order of the action of a hunting governor on a gas engine. Its unsteady action was supposed to be due to the two sudden or too slow action of the control valve which threw on or released the pressure instantaneously. This caused the wagon to move along very easy one moment and hard the next, having its rear wheels almost locked due to the heavy pressure placed on the pump, which was run indirectly thru the rear wheels. It was noticed that the control valve rod did not act in harmony with the control rod but appeared to have a lag of several seconds, both on the building and the release of the pressure. The weights on the rear of the wagon, swung violently, often bumping into the wheels and thus losing their effectiveness. The wagon was returned to the building as was the case after every trial, where new designs for the defective parts were figured out and placed in position.

The weights on the rear end of the cables were removed and iron buckets one foot in diameter by one foot high (B in picture 7) were fastened in their places. This arrangement had the advantage of being able to use adjustable loads by varying the weights in the buckets. To protect the wheels from the buckets, and also to act as a guide to take much of the swinging action from the buckets, a shield was made of sheet iron and fastened to the rear of the frame. This allowed the buckets to swing free but kept them from too violent action. The buckets were too high to allow a play of 18 inches under the frame, so extensions had to be made on the rear of the frame. Two angle irons were fitted to the rear frame so that they would extend out over the end eight inches, and were fastened to the frame by three cap screws apiece. (D in pictures 10 and 11) The top bar in the rear to which the sheaves were fastened was then moved out to the ends of these angle irons and secured by bolts. (A in picture 11) This arrangement allowed the buckets to be drawn upward for a distance of 18 inches as were the weights. The buckets gave the added advantage of allowing the load to be adjustable almost immediately for each horse, by the addition or the removal of the weights in the buckets. In order to bring the adjustment down to fine points, lead blocks weighing five pounds each were cast for use in the buckets.

Second Trial and Redesign of Defects

When the wagon was taken out upon its second trial it was noticed that the throbbing action had not been eliminated or helped in any way. Even when the buckets were loaded up to 200 pounds or more the wagon had the same unsteady action as before. The control valve was then taken off and examined which revealed the fact that it really did lag two seconds before or behind action. In order to damper this effect and also the quick changing action of the control rod, it was decided to place a dash pot in the action which was to act as a buffer to the cable bar. This was supposed to check the unsteady action of the control valve and maybe remedy the defect altogether.

A pump cylinder about a foot in length and having a three inch hole was procured and fixed up to form a dash pot. The bottom of the cylinder was securely closed by means of a bushing and a plug. The valve on the plunger rod was screwed down tight, allowing no action of the valve to take place, and the top was screwed on firmly. The end of the plunger was threaded and fixed up so that a clevis could be attached to it, and the other end of the clevis fastened to the center of the cable bar. The small cable Bar used during the first test was disconnected because with the added pressure of the dash pot it would be too small to take the pressure. A large cable bar was then made to dimensions $\frac{1}{2}$"x2"x33" and was fastened to the cable by means of special cable clamp hooks. (D in picture

9) The dash pot (A in picture 12) was fitted up with a bypass made of pipes in the manner shown; the valve being used for the application or release of pressure. The plug in the end of the pipe allowed for the refilling of the pot with oil when necessary.

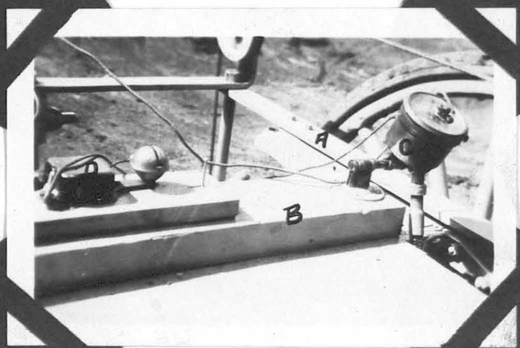
The cable bar then was made to operate more smoothly which caused the valve rod to act more evenly, thus smoothing out the unsteady action considerably. The buckets were made to hang about seven inches from the ground and in order to accomplish this thruout the tests, some method of cable adjustment had to be figured out.

Four large hooks (A in picture 8) were forged and fastened to the cables by means of attached cable clamps. Chains connecting these hooks made easy adjustment possible and made the adjustment of the heights of the buckets easy. Chains show connecting hooks in (B picture 8). The ends of the cable bar were bolted to the two hooks which made a firm joint, allowing the one cable to get 18"in front of the other before the cable would bind on the other clamp. The dash pot was elevated to the height of eight inches by means of wooden blocks (B in 12) so that the plunger rod was of the same height as the cable bar, and bolted to the wagon by two U-bolts. (C in 12). In order to further reduce the action of the valve control rod, a linkage was fastened to the cable bar on the one end and to the cable bar rod on the other thru the eye bolt.

Trial Three and Redesign of Defects.

The placing of the dash pot in the system did have some good effects upon the operation because the action was very much smoother than before its addition. The throbbing motion still existed however, but it did show us that we were on the right track in the methods of remedying its defects. The old lagging control valve was removed and a new steam governor valve was put in its place. The linkage was found to have no effects at all on the action so it was removed; and the cable bar rod was again returned to its eye socket on the cable bar. The rod from the cable bar rod to the plunger rod was changed, and one capable of being made adjustable put in its place. (C in picture 10).

A platform was built to fit up in the front part of the wagon, so as to be an aid to the driver. It was made of one inch pine flooring which was fitted between the wagon frame and held together by two 2"x4" braces nailed at each end. Another 2"x4" was nailed on top (B of picture 14) so as to be used for a foot brace and also a holder for the speedometer and warning bell. The speedometer was so constructed that when one hand was set at a certain number on the dial and when the indicator hand reached this number the electric circuit, to which these hands were wired, would be closed and the warning bell would ring. The purpose of this meter was to keep the wagon as nearly as possible at the desired speed.



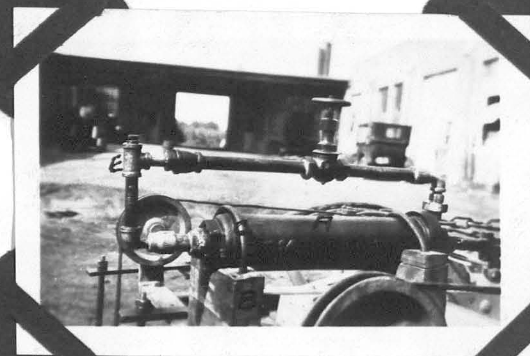
Picture 14

A-Brace-bar on frame

B-Front platform and dash

C-Speedometer

D- Warning bell



Picture 12

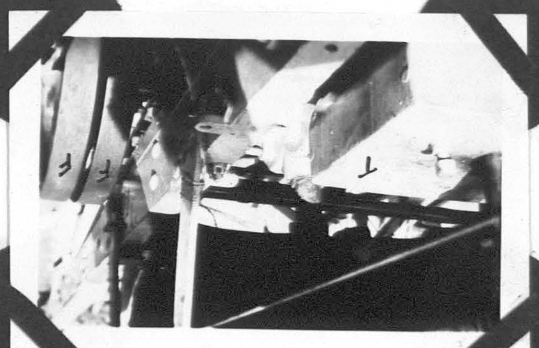
A-Pump cylinder converted into dashpot

B-Wood spacing blocks

C- U-bolts

D-Dash-pot valve

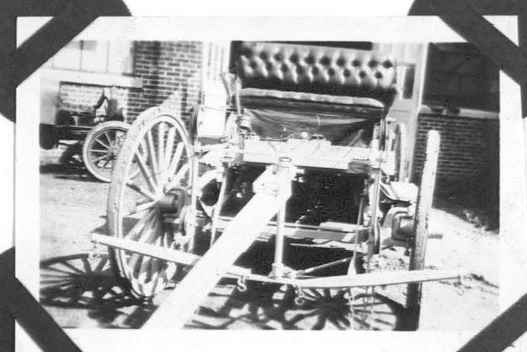
E-Oil refilling opening



Picture 2

T-Tank

F-Flywheel



Picture 4

Front view of wagon before fifth trial

Trial Four and Redesign of Defects.

During this trial the wagon worked fairly well having much of the uneven action smoothed out. The new valve control worked very much better than the old lagging one and proved itself more efficient than the latter. The small pulsations of the wagon were still evident but the uneveness was smoothed out almost entirely when the brake on the rear wheel drums was applied, The buckets were held from swinging and this too added wonderfully to the steadiness of the action. This gave us the idea that brake pressure should be applied to the pump so as to make it act more evenly and smoothly and hold the pressure constant. Some method should also be figured out to hold the buckets from their swaying motion and still allow them to hang and act free. It was noticed that the swinging of the buckets caused a certain jar to be transmitted to the cable bar which in turn imparted it to the control valve thus aiding in the formation of the small pulsations by causing uneveness of pressure.

In order to bring about a constant pressure in the pump, a two inch globe valve of the angle type was procured and the threads on the control stem were ground down. A coil spring was placed on this valve which transformed it into a steady pressure valve, which would release excessive pressures above that of the spring pressure, thus keeping the pressure on the pump constant and giving the desired brake action. The valve was placed in the two inch pipe line from the top of the con-

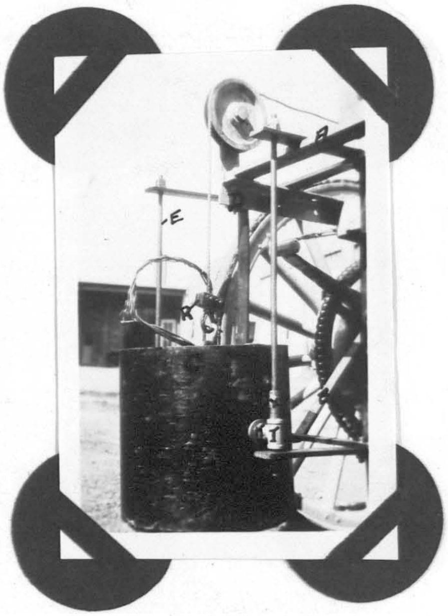
control valve outlet to the tank return entrance.

Two flywheels were placed on the pump shaft so as to aid the pump in retaining a uniform speed and holding the smooth action.

The buckets were kept from swinging but still allowed to hang free by means of specially designed guides.

Two pieces of iron bar were cut to dimensions 3/8" x$1\frac{1}{2}$"x48" and placed on the rear end of the wagon; the one was bolted to the angle irons on top and the other was held at the bottom by two 3/8"x1" iron braces, attached to the wagon frame. (D and E in picture 10) (B in picture 11).

Four bars of iron were then cut to correct dimensions and bent at right angles ten inches from each end. (I in picture 10) Three-eights inch rods were then cut and threaded at both ends and these fitted to the E - shaped irons in the holes drilled at both ends of the irons eight inches from the angle. The E- shaped irons were measured and correctly fitted to the top and bottom bars (D and E of picture 10) as shown. The iron buckets were centered on two sides and two one-half inch holes drilled in the center of each side center line. Pipe tees were fitted to these iron rods (I picture 11) and a small piece of pipe attached to each end of the tee as shown in (X picture 11). This allowed the tee to slide on the rods without any tendency to bind and without being too loose, so as to allow a swaying motion. Cap screws



Picture 11

A- Rear top-bar holding sheaves

B-Rear frame brace

C- Bucket

D-Angle brace holding framework

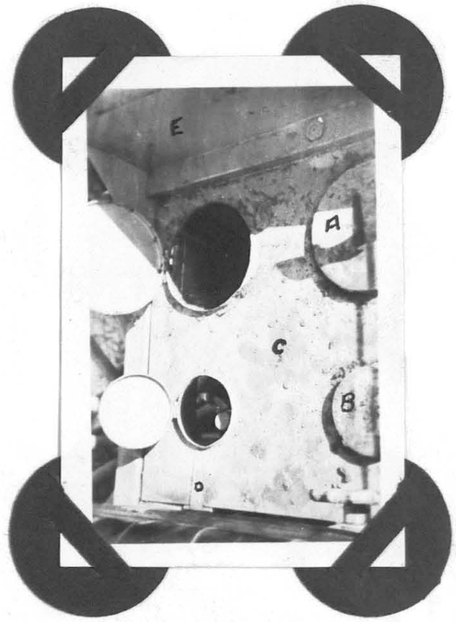
E- Bucket rod

I-Pipe-tee forming slider on rod

K- Cap-screw and lock-nut

X-Pipe slider on slider-tee

R-Cable clamp attachment



Picture 16

A-Large opening infront platform floor for feces containers

B-Small opening for urine container

C-Front platform; hinged

E- Dash

placed with their heads on the inside of the buckets, were screwed into the side openings of the tees and thus formed a loose joint which permitted a motion parallel to the direction of the wagon motion, with the cap screw as the center of motion, but allowing no side motion. The swaying motion of the buckets from side to side was thus checked but the buckets still hung free. (K in picture 11) shows this joint assembled. The sliding guiders on the rods allowed the buckets to be drawn up and down on the rods, but checked the side action which was part cause for the throbbing action of the wagon. The cap screws were locked in place by lock nuts on the outside of the buckets and between the buckets and the tees.

Trial Five and Redesign of Defects.

During this trial the wagon moved along smoothly, with but very little of the throbbing motion present. The wagon could now be used for the test desired.

Later Additions to Wagon to Aid in Perfection.

In order to count the number of miles traveled per day an odometer was designed. A small veeder odometer was attached to a hook shaped arrangement which fastened to the spokes of one of the front wheels of the wagon. A weight attached to the veedometer shaft in the form of a crank completed the instrument. The operation was as follows: When the wheel revolved, the hook and veedometer were carried around with it but the weight on the crank fastened to the veeder odometer shaft always hung downward and thus the veeder odometer was revolved around its shaft instead of the usual way of having the shaft revolve in the instrument, thus registering the number of miles traveled.

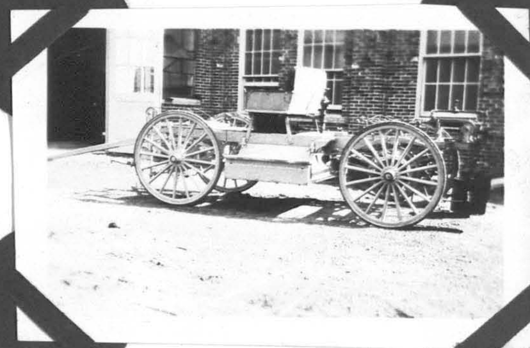
Oil was placed in tank instead of water.

A spring valve which was capable of being controlled from the driver's seat was next added, and placed on the return flow water pipe from the pump to the tank thus allowing any pressure to be placed on the pump and thus tending to hold the pressure even. This was later removed in favor of a valve which registered true value of pull on the horses.

The seat was next removed and placed further front toward the horses and placed on hinge-like rods, (shown in picture 18) so that any of the machinery under the seat would be easily accessible at any time. A platform was then built and placed in the front of the wagon so as to hold the cans and jugs for the feces and liquids of the horses collected during the run. A new floor was next placed in front of the seat and designed so that doors opened into the jugs and cans directly beneath them (shown in picture 16) Two or three other valves were tried out on the wagon in an effort to get a perfectly smooth moving wagon at all weights. Most of the latter valves worked all right but had a percent of error due to taking some weight off the horses. The last valve tried out on the wagon proved to be absolutely without error.

Picture 1

Front,side view of wagon before fifth trial



Picture 20

Rear,side view of wagon before fifth trial

Picture 17

Front,side view of wagon just before the final change

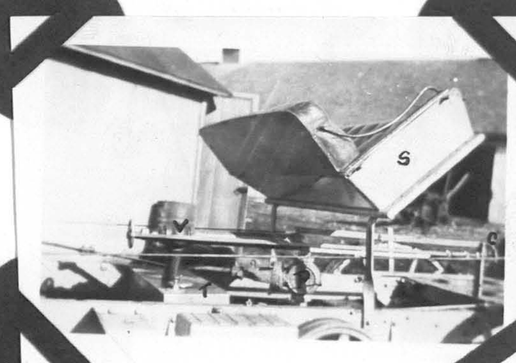
A- Feces container

B-Battery box

C-Dash

S-New hinge-action seat

V- Spring valve



Picture 18

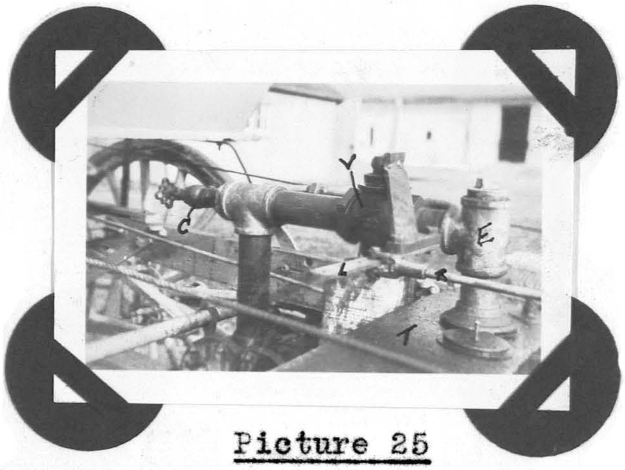
C- Spring valve control

V- Valve spring

P-Pump valve

T-Tank

S-Seat raised to show accessibility to machinery under seat



Picture 25

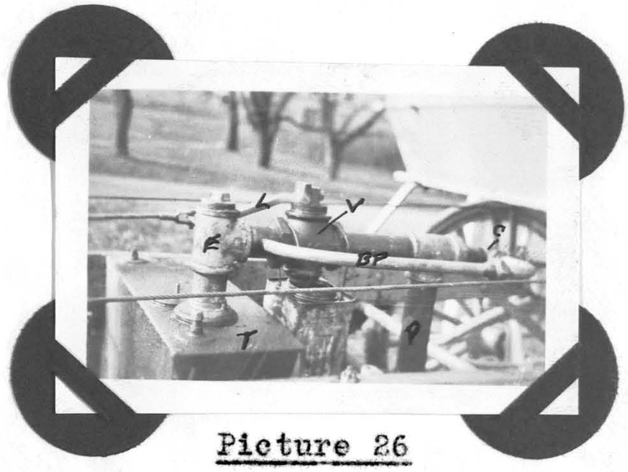
C- Control valve for by-pass

E- Entrance to tank

L- Valve control rod

V- Control valve for pump

Pictures 25 and 26 show the latest form of valve used



Picture 26

C- Control valve for by-pass

E- Entrance to tank

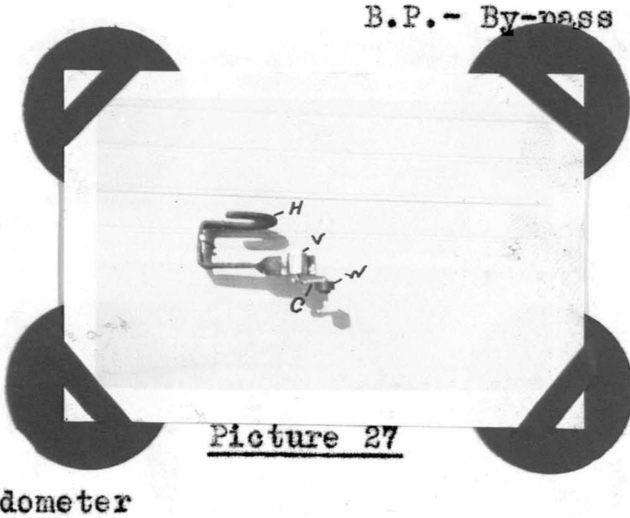
L- Valve lever

P- Pipe to pump

T- Tank

V- Control valve for pump

B.P.- By-pass pipe



Picture 27

Odometer

C- Crank

H- Fastening hook

V- Veedometer

W- Weight on crank

This valve was an iron cock valve with the same diameter as the globe valve mentioned before. The valve head was directly connected to a short adjustable lever which was attached directly to the cable bar. Thus the action of the cables drawn by the horses raised the buckets containing the weights and the cable bar going forward acted upon the valve rod which in turn acted upon the valve adjusting it to all variations. A by pass was placed on the valve so as to allow the backing up of the wagon. (picture shows the valve) The action of this valve was almost perfect and the former error of taking some of the weight off the horses was also overcome here so that the wagon was as complete, and the action as steady, as could be expected and more than filled expectations.

Conclusions.

As the results of running this test have not been collected and as the test is still very young, no real conclusions as to their working out can be drawn. There are however, several actions which are expected to happen and it will be interesting to note just how all the results turn out. There are also several well known theories with respect to the amount of weight a horse can pull for his weight, etc. Will the test approve or disapprove these theories?

The test will be carried on by first selecting two horses of the draft type. The horses should be used to doing hard work daily so that when placed in the wagon will be able to continue the work without any failures. At one period of the test the horses will be placed under strict care and attention in preparation for the efficiency test. The relations between the amount of work done and the feed required will be then tested. All feed is weighed before given to the horses and all the feces and urine is caught in separate containers for each horse. While at work special buckets are placed on the wagon for eadh horse and in the stable a special watch must be made so as to catch all feces and urine. The analysis of the feeds, feces and urine will give some relation as to the efficiency of the horses.

It is not exactly known just what the effect of the relation between the eight hours working time without rest and with intermittent periods of rest will be put it is thought that it will be somewhat similar to man. A man can do much greater amount of work if permitted to rest at intermals than when working steady and it is believed that the horse will perform in he same manner.

The idea was formed while time studies and motion studies of men were being taken. On further examination it has proven to be one of the most important discoveries of time study.

Under the old, and still much used methods, the common idea was to keep a man as busy as possible during the entire working period for which he has been engaged. It now appears that he will do more and better work if given periodic rests. All are fairly familiar with the phenomena of fatigue. In beginning work there is a period during which effort is not only easy but agreeable, and the rate of production increases. Then follows a period during which conditions are uniform, succeeded in turn by a decline in interest and pleasure in production, straining begins to be felt and finally, if the effort is continued, pain appears. During this latter period the worker must put forth his will power to continue at the task, "working on his nerve" as is said, and at last if the effort is continued, it becomes unbearable and complete exhaustion takes place.

Physical or mental effort of any kind results in the breaking down of tissues which creates certain toxic poisons in the blood giving rise thereby to the phenomena described. If the effort is slow the system reacts fast enough to dispose of these waste products as fast as they are formed, but it cannot perform this cleansing action against great and continued effort. Recovery from moderate fatigue is rapid, but the recovery from great effort is slow and as the worker gets older it is less and less complete. It is a well known fact that violent exertion on the part of old people is dangerous. Fatigue within the "elastic limit", however, is wholesome for everyone and good health cannot be maintained without some bodily effort. It should be also remembered that change of work is relative rest and not as liable to tire out a worker as a special process. We have little or no data as yet that can be used as a guide in fixing rest periods. Experimental psychologists have done considerable experimental work but so far there results have been expressed in very general statements. It is well known also, that fatigue is a function of the speed of performance for we exhaust ourselves much more by doing a given task quickly than by doing it slowly.

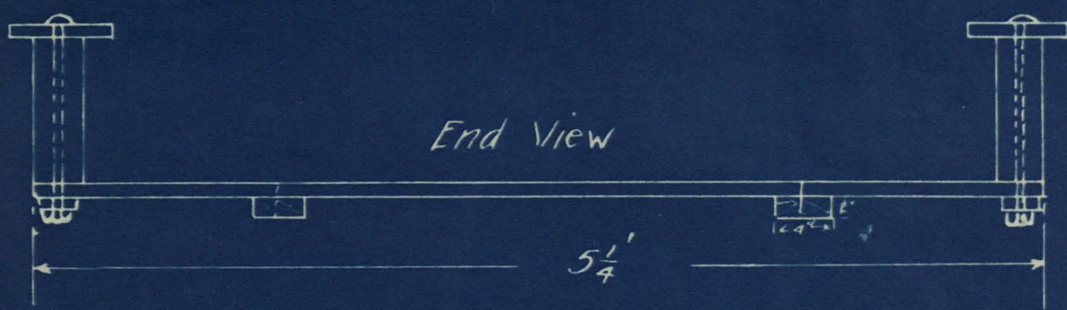
It is believed that the horse will react on somewhat the same principles as man and so valuable data on man's fatigue may be applied to horses also.

After the main issues have been worked upon and a conclusion arrived at, then various other phases of the horse in connection to his work will be brought out and tried, making this test the beginning of a complete test of the horse. Even though horses have been used for man's work for ages, notmuch useful data has been recorded. Should this test prove as successful as is predected, then this test will mark the beginning of numerous investigations and available data upon horses from all angles possible.

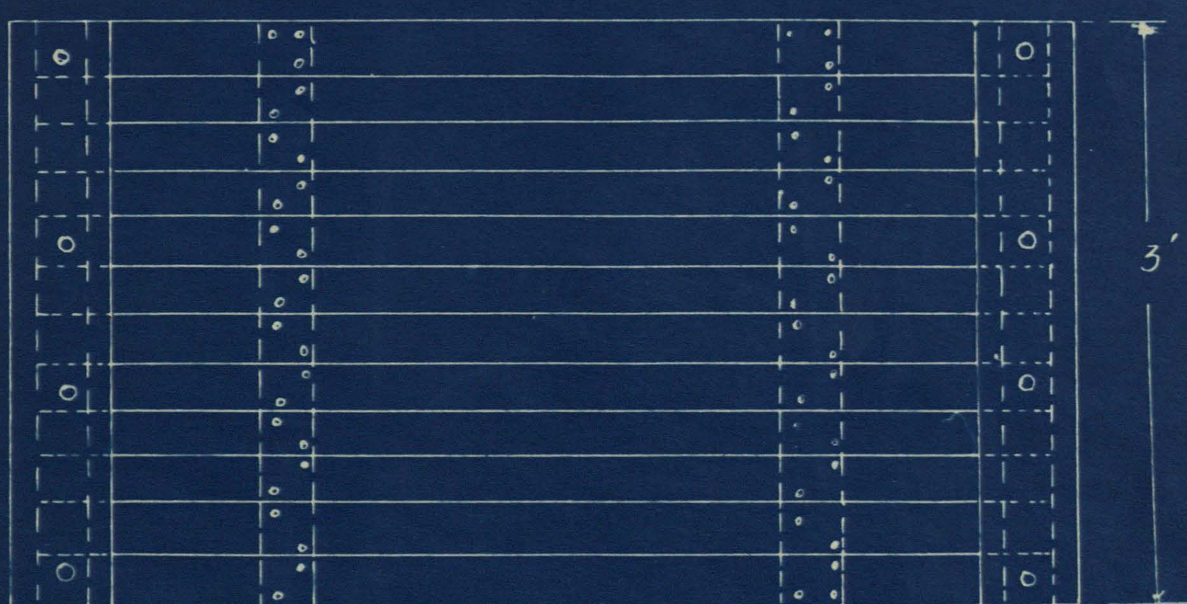
Eventually the tests of the horse and the tractor will be compared so as to find the place for each and instead of competition to replace one another, there will be a co-operation that will prove most advantageous to both.

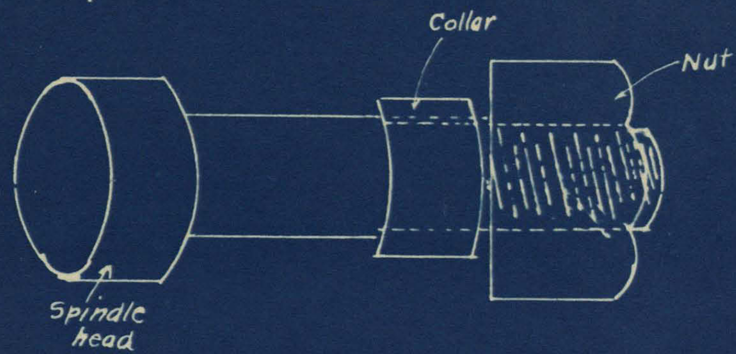
Under-slung Platform

Scale 1" = 1'

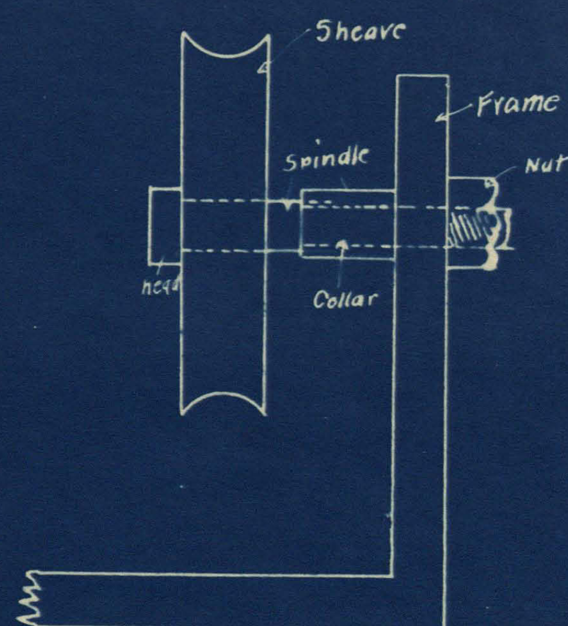


Top View

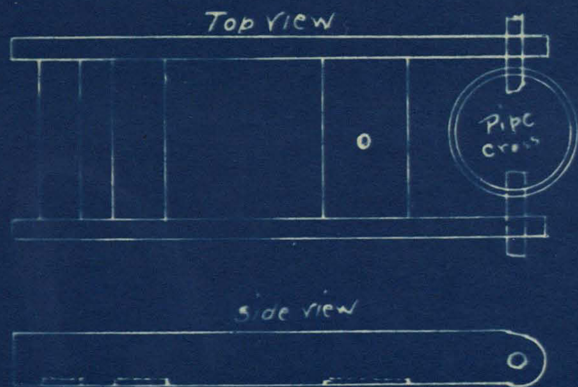


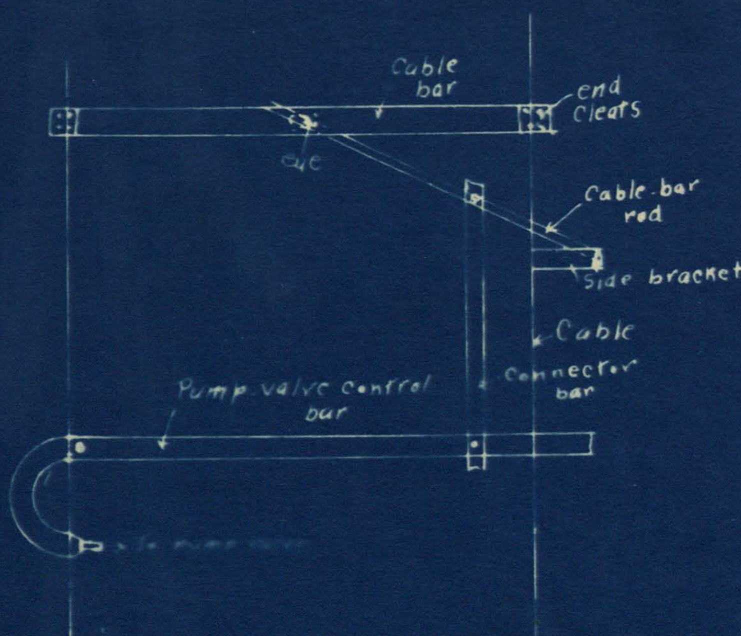


Spindle



Method of fastening sheave to frame





First Automatic Control mechanism